IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA,	)	
	)	
Plaintiff,	)	
	)	
v.	)	Case No. 05-cv-329-GKF(PJC)
	)	
TYSON FOODS, INC., et al.,	)	
	)	
Defendants.	)	

DECLARATION OF J. BERTON FISHER, Ph.D.

I, J. Berton Fisher, Ph.D., hereby declare as follows:

1. I am a geochemist and geologist with expertise in the transport and fate of materials in the environment. I hold a Ph.D. and M.S. in Earth Sciences from Case Western Reserve University and a B.S. in Geology and Geophysics from Yale University. I am a Certified Professional Geologist, a Registered Professional Geoscientist in the State of Texas and a Registered Professional Geologist in the State of Mississippi. I have published scientific papers regarding technical environmental matters in peer-reviewed publications, and I have given numerous technical presentations regarding environmental matters at scientific meetings. I have worked on the engineering and scientific aspects of numerous environmental litigation, regulatory and transaction matters, including, specifically, environmental matters related to the land disposal of poultry wastes. I have worked professionally as a geochemist and geologist since 1973 and have worked on matters related to agricultural, industrial, petroleum and mining environmental contamination for nearly twenty-five years. My work experience includes consulting, industrial and academic positions. My experience in technical environmental matters includes site investigations, review of site investigation data, analysis of the chemical and physical characteristics of environmental samples, historic research on industrial and agricultural activities and processes, petroleum exploration and production, mining, the environmental chemistry of organic and inorganic contaminants and studies of the fate and transport of organic and inorganic contaminants in soils, sediments and water, including the collection of undisturbed cores of unconsolidated lake sediment and the geochronological analysis of undisturbed cores of unconsolidated lake sediments using natural and anthropogenic radioactive nuclides and paleontological markers.

2. Since 1997 1 have worked on matters related to the environmental contamination by poultry wastes, including the chemistry, generation and land disposal of poultry wastes, the identification of poultry waste constituents in the environment, their fate and transport in the environment, the effects of poultry waste contaminants on water quality, and the management of poultry waste land disposal in eastern Oklahoma and western

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Arkansas. I have served as a consultant to the Tulsa Metropolitan Utility Authority and the City of Tulsa with respect to poultry waste issues from 1997 to the present.

3. I was retained by the Oklahoma Attorney General, beginning in 2004, to evaluate, provide analysis and advise on matters pertaining to poultry waste generation, poultry waste disposal practices and the fate and transport of land applied poultry waste.

4. On May 15, 2008, I submitted an Expert Report (attached hereto as Attachment A) to the Defendants in the above-captioned litigation.

5. The following statements, findings and opinions are taken verbatim from my Expert Report.

6. ODAFF records[], nutrient management plans in Defendants' discovery documents[], and investigator notes[] demonstrate that poultry waste has been applied on pasture and grasslands throughout both the Oklahoma and Arkansas portions of the Illinois River Watershed. Shown in Fig. 6 [attached hereto as Attachment B] are Public Land Survey sections in which poultry waste is known to have been disposed within the Illinois River Watershed based on ODAFF records, investigator reports and discovery documents. This map demonstrates that poultry waste disposal is widespread throughout grassland and pasture areas within the Illinois River Watershed.

(Expert Report, ¶ 11) (footnotes omitted).

7. **The geology of the Illinois River Watershed produces a circumstance in which both the surface and ground water within the Illinois River Watershed are highly susceptible to pollution from the constituents of land applied poultry waste.** The Illinois River Watershed contains approximately 1,672 mi^2 (1,069,530 acres), and lies within the southwestern portion (Springfield Plateau) of the Ozark Uplift physiographic province within portions of Washington and Benton Counties in Arkansas and Delaware, Adair, Cherokee and Sequoyah Counties in Oklahoma. Approximately 53% of the Illinois River Watershed is in Oklahoma and the remaining 47% is in Arkansas.[ ] The Springfield plateau is generally deeply dissected with rolling upland areas separated by V-shaped stream valleys that range from 20 to 30 feet in depth.

(Expert Report, ¶ 19) (footnote omitted).

8. [T]he Illinois River arises in the Boston Mountains of northwestern Arkansas in Washington County. From its headwaters, it flows in a northerly and westerly direction to its crossing of the Oklahoma/Arkansas border south of Siloam Springs in Benton County, Arkansas. From there, the Illinois continues westerly to its confluence with Flint Creek in Delaware County, Oklahoma where it changes course to a southerly direction. The Illinois is impounded by Tenkiller dam just north of its confluence with the Arkansas River at Gore, Oklahoma. From its headwaters to its confluence with the Arkansas, the Illinois flows approximately 162 miles.

(Expert Report, ¶ 19).

9. Two of the primary tributaries to the Illinois River also arise in the Ozark region of Arkansas. Flint Creek originates in Benton County and flows generally westerly toward its confluence with the Illinois just south of Kansas, Oklahoma. Baron Fork Creek arises in Washington County, Arkansas and flows southwesterly to its confluence with the Illinois south of Tahlequah, Oklahoma. The third major tributary to the Illinois River, Caney Creek, originates at Stillwell, Oklahoma, and flows generally southwesterly to its confluence with the Illinois in the northern portion of Lake Tenkiller.

(Expert Report, ¶ 19).

10. Surface water movement within the Illinois River Watershed is controlled by its underlying geology. The major streams in the Illinois River Watershed (Illinois River, Flint Creek, Baron Fork and Caney Creek) have developed within geological faults and fractures. [ ] ...[T]hese streams flow westerly and southwesterly, and become, in general, progressively more deeply incised as they pass from the Arkansas portion of the Illinois River Watershed to the Oklahoma portion of the Illinois River Watershed. ...[T]he Arkansas portion of Illinois River Watershed is dominated by broad open grassed areas of low topographic relief that are dissected by numerous tributary drainages. In contrast, in the Oklahoma portion of the Illinois River Watershed, topographic relief is greater, and the major streams there form broader more steeply-sided forested valleys that separate more isolated grassed areas. Urban areas within the Illinois River Watershed are located largely along the watershed's boundary, dominantly along the far northeastern boundary of the watershed, and adjacent to the primary east-west transportation corridor. Simply stated, the Arkansas portion of the Illinois River Watershed is more open, contains a greater proportion of pasture land and those pasturelands are more contiguous in Arkansas than in Oklahoma. This condition facilitates the disposal of poultry wastes through land application. In contrast, the Oklahoma portion of the Illinois River Watershed is generally hillier, going westward and southwestward, and thus becomes less topographically suitable for the disposal of poultry wastes through land application traveling from east to west.

(Expert Report, ¶ 19) (footnote omitted).

11. Structural features found in the region suggest episodes of uplift and extensional stress. Compressional forces are attributed to the Ouachita orogeny, a plate collision that climaxed in the Mississippian. [ ] Extensional forces are represented by large-scale normal faults, dipping to the south that commonly extend to basement [ ], and smaller scale faulting on the order of 30 m displacements. [ ] Joints are common and appear to be controlled by uplift that resulted in extensional fractures. The faults and fractures that control drainage within the Illinois River Watershed are primarily associated with the Ozark uplift. The Ozark uplift postdates the deposition of the youngest bedrock (Mississippian) within the Illinois River watershed. [ ] As a result, this uplift disturbed all strata within the Illinois River Watershed. Consequently, significant fracturing and faulting observed at the surface within the Illinois River Watershed penetrates deeply into

all of the geologic formations within the Illinois River Watershed. This deep fracturing is significant, because its presence means that the constituents from land application of poultry waste can not only easily move into shallow aquifers along dissolution-expanded (karsted) infiltration routes, it can also penetrate to greater depths along the deep seated fractures and faults, and thus threaten deeper aquifers....

(Expert Report, ¶ 19) (footnotes omitted).

12. The terrain of the bulk of the Illinois River Watershed is mantled karst. [ ] In mantled karst terrains the dissolution of carbonate units beneath a covering of soil and regolith creates expanded infiltration pathways, including, sinkholes, solution expanded fractures, faults and caves. The fracturing and faulting within the Illinois River Watershed, combined with karstification (which enlarges subsurface faults and fractures), produces areas of high permeability, and results in a circumstance in which shallow ground water aquifers are particularly susceptible to impact by surface contamination, including contamination by bacteria, that can readily travel from the soil surface to surface water and ground water during rainfall events.... Within such a karst terrain, there is little attenuation (reduction) of contaminants as they move from the land surface into and through the karst aquifer. Thus, land application of poultry waste to the karst terrain of the Illinois River Watershed means that constituents of this waste (including bacteria) travel readily through the soils and underlying geologic media to discharge at and into ground water springs and surface streams throughout the Illinois River Watershed. Further, because of the ready flow of water through a karst terrain of the type present in the Illinois River Watershed, there is strong interaction between surface water flow and ground water flow so that surface waters readily become ground water and ground water readily becomes surface water. The phenomenon is readily shown by the numerous springs and gaining and losing streams found within the Illinois River Watershed.

(Expert Report, ¶ 19) (footnote omitted).

13. Soils within the Illinois River Watershed are formed mostly from the weathering of carbonate rocks, and are of low natural fertility. [] The soils are typically loams and are often rocky due to the presence of chert fragments. Loam soils are mixtures of sand, silt, clay and organic matter. Depending on the relative proportion of sand, silt and clay, these soils will be susceptible to infiltration or surface runoff. [ ] ...[S]oils more susceptible to run off dominate in the eastern and western portions of the Illinois River Watershed, while soils that are more susceptible to infiltration dominate in the central portion of the Illinois River Watershed.[ ] Thus, contaminants deposited on the surface within the Illinois River Watershed are prone to runoff from soils in about half of the watershed and are prone to infiltration through soils in the remaining half of the watershed.

(Expert Report, ¶ 19) (footnotes omitted).

14. **Shallow ground water within the Illinois River Watershed is highly susceptible to contamination from surface-applied pollutants.** The shallow bedrock

aquifer within the Springfield Plateau of the Ozark Uplift is the Boone. The Boone aquifer consists of the Mississippian Keokuk and Reeds Spring formations and the St. Joe Group, commonly called the Boone Chert or Boone Formation. The Boone Formation consists of dense, fine-grained limestone and massive gray chert. Where the chert is fractured, the formations are permeable [ ]. The Boone aquifer is absent because of erosion in a few areas in Delaware, Cherokee, and Adair counties, Oklahoma. In these areas the Chattanooga Shale of Devonian age and the Burgen Sandstone, Sylvan Shale, and Cotter Dolomite of Ordovician age are exposed at the surface. The Burgen Sandstone and Cotter Dolomite are part of the underlying Roubidoux aquifer. [ ]

(Expert Report, ¶ 20) (footnotes omitted).

15. The vulnerability of the Boone aquifer within the area of the Illinois River Watershed to pollution from surface-applied contaminants has been addressed in both Oklahoma [ ] and Arkansas [ ]. The aquifer vulnerability analysis conducted in Oklahoma and in Arkansas considered the same factors: (1) depth to water, (2) net recharge, (3) soil media, (4) topography, (5) vadose zone media; and (6) aquifer hydraulic conductivity.

(Expert Report, ¶ 20) (footnotes omitted).

16. The depth to water is the distance, in feet, from the ground surface to the water table. It determines the depth of material through which a contaminant must travel before reaching the aquifer. The shallower the water depth, the more vulnerable the aquifer is to pollution.

(Expert Report, ¶ 20).

17. The primary source of recharge is precipitation, which infiltrates through the ground surface and percolates to the water table. Net recharge is the total quantity of water per unit area, in inches per year, which reaches the water table. Recharge is the principal vehicle for leaching and transporting contaminants to the water table. As recharge rate increases, opportunity for contaminants to reach the water table increases.

(Expert Report, ¶ 20).

18. Soil media is the upper weathered zone of the earth, which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge that can infiltrate into the ground. In general, the less the clay shrinks and swells and the smaller the grain size of the soil, the less likely contaminants will reach the water table.

(Expert Report, ¶ 20).

19. Topography refers to the slope of the land surface. Topography helps control the likelihood that a pollutant will run off or remain long enough to infiltrate through the ground surface. Where slopes are low, runoff is small, and the potential for pollution via

infiltration is greater. Conversely, where slopes are steep, runoff capacity is high and the potential for pollution to reach ground water via infiltration is lower.

(Expert Report, ¶ 20).

20. The vadose zone is the unsaturated zone above the water table. The texture of the vadose zone determines the time of travel of the contaminant through it. Coarse textured materials allow, in general, more rapid transport than finely textured materials.

(Expert Report, ¶ 20).

21. Hydraulic conductivity refers to the rate at which water flows horizontally through an aquifer. Aquifer vulnerability increases with increasing hydraulic conductivity.

(Expert Report, ¶ 20).

22. In Oklahoma, the Boone was among the four bedrock aquifers considered highly vulnerable to surface contamination because it contains karst features such as caves, sinkholes, and disappearing streams, which provide direct conduits for precipitation and runoff to transport contaminants to the water table.

(Expert Report, ¶ 20).

23. Recharge to the Boone hydrogeologic basin is almost entirely from direct infiltration of precipitation. The factors that make the outcrop of the Boone Formation favorable to ground water recharge also make it vulnerable to contamination. Because soil and subsoil in the Ozarks is thin, near-surface faults and fracture systems are common, and dissolution of the carbonate rocks is widespread, precipitation can quickly infiltrate the unsaturated zone.

24. Based on a review of Oklahoma Water Resources Board and Arkansas Geological Survey well records [ ] there are 3,563 ground water wells in the Illinois River Watershed including 1,717 wells in the Oklahoma portion of the Illinois River Watershed. The vast majority of the wells in the Oklahoma portion of the Illinois River Watershed (1,679 of 1,717 wells, or 98%) are registered for "Domestic" use (for drinking and other household purposes), and about 50% of the wells in Oklahoma are shallow (i.e. less than 200' total depth). Based on my experience and observations these domestic wells do not typically employ treatment systems that would eliminate any bacterial hazard. Given the above analysis of the geology and terrain of the Illinois River Watershed, surface water contaminated with land applied poultry waste will readily travel to shallow, and often deep, ground water aquifers.

(Expert Report, ¶ 20) (footnote omitted).

25. The analysis conducted for the Arkansas portion of the Illinois River watershed [ ] is more detailed spatially, and predicts that the highest areas of aquifer vulnerability are within fractures, stream courses and on slopes.

(Expert Report, ¶ 20) (footnote omitted).

26. Considering the numerous factors in play that permit surface-applied contaminants to enter groundwater, the karst of northwestern Arkansas and northeastern Oklahoma is vulnerable to ground-water contamination because of the unique geology of the region in combination with the large volume of poultry waste spread on pasture land as fertilizer. The waste produced by more than 1 billion chickens and other poultry, and livestock operations constitutes a threat to ground-water quality because of rapid recharge of ground water through karst features and associated conduit flow of ground water through the bedrock.[ ].

(Expert Report, ¶ 20) (footnote omitted).

27. **Constituents of land disposed poultrv waste run off fields and surface water and infiltrate through geologic media and contaminate ground water and are poorly attenuated.** Poultry waste is disposed on fields within the Illinois River Watershed by simple broadcast spreading. The poultry waste is not mechanically incorporated into soils. As a consequence, both soluble and particulate fractions of this material are readily available for transportation through the agency of rainfall. When rain interacts with poultry waste, some of the material goes into solution. This dissolved material can then travel with the water as it moves downward through the soil and vadose zone to pollute the ground water. Additionally, if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e. not all of the water can be taken up by the soil and it runs off the field). The dissolved material derived from the poultry waste will also move with the runoff and pollute surface water. Further, this runoff water can also carry particles of poultry waste that will pollute surface water, stream sediments and lake sediments. Because pores can be large in karst, particles can also be transported through the ground water in karst aquifers. Both runoff and ground water eventually end up in surface streams that flow to Lake Tenkiller. Thus pollution of the surface of the ground by the disposal of poultry waste as practiced within the Illinois River Watershed results in the pollution of surface water, ground water, stream sediments and lake sediments.

(Expert Report, ¶ 21).

I declare, under penalty of perjury, under the laws of the United States of America, that the foregoing is true and correct.

Executed on the 14TH day of May, 2009.

J. Berton Fisher, Ph.D.

In the matter of

State of Oklahoma, ex rel., A. Drew Edmondson in his capacity as Attorney General of the State of Oklahoma, and Oklahoma Secretary of the Environment, C. MILES TOLBERT, in his capacity as the Trustee for Natural Resources for the State of Oklahoma, Plaintiffs

v.

Tyson Foods, Tyson Poultry, Tyson Chicken, Inc., Cobb-Vantress, Inc., Aviagen, Inc., Cal-Maine Foods, Cal-Mane Farms, Inc. Cargill, Inc., Cargill Turkey Products, LLC, George's, Inc., George's Farms, Inc., Peterson Farms, Inc., Simmons Foods, Inc. and Willowbrook Foods, Inc., Defendants.

CASE NO. 05-CV-329- GFK-SAJ

in the United States District Court
for the Northern District of Oklahoma

Expert Report

of

J. Berton Fisher, Ph.D., CPG, RPG (TX #0201; MS#0301)
Lithochimeia, Inc.
110 West 7th Street, Suite 105
Tulsa, Oklahoma 74119
May 15, 2008

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Introduction

Summary of Qualifications

I am a geochemist and geologist with expertise in the transport and fate of materials in the environment. I hold a Ph.D. and M.S. in Earth Sciences from Case Western Reserve University and a B.S. in Geology and Geophysics from Yale University. I am a Certified Professional Geologist, a Registered Professional Geoscientist in the State of Texas and a Registered Professional Geologist in the State of Mississippi. I have published scientific papers regarding technical environmental matters in peer-reviewed publications, and I have given numerous technical presentations regarding environmental matters at scientific meetings. I have worked on the engineering and scientific aspects of numerous environmental litigation, regulatory and transaction matters, including, specifically, environmental matters related to the land disposal of poultry wastes. I have worked professionally as a geochemist and geologist since 1973 and have worked on matters related to agricultural, industrial, petroleum and mining environmental contamination for nearly twenty-five years. My work experience includes consulting, industrial and academic positions. My experience in technical environmental matters includes site investigations, review of site investigation data, analysis of the chemical and physical characteristics of environmental samples, historic research on industrial and agricultural activities and processes, petroleum exploration and production, mining, the environmental chemistry of organic and inorganic contaminants and studies of the fate and transport of organic and inorganic contaminants in soils, sediments and water, including the collection of undisturbed cores of unconsolidated lake sediment and the geochronological analysis of undisturbed cores of unconsolidated lake sediments using natural and anthropogenic radioactive nuclides and paleontological markers.

Since 1997 I have worked on matters related to the environmental contamination by poultry wastes including the chemistry, generation and land disposal of poultry wastes, the identification of poultry waste constituents in the environment, their fate and transport in the environment, the effects of poultry waste contaminants on water quality, and the management of poultry waste land disposal in eastern Oklahoma and western Arkansas. I have served as a consultant to the Tulsa Metropolitan Utility Authority and the City of Tulsa with respect to poultry waste issues from 1997 to the present.

Retention and Purpose Thereof

I was retained by the Oklahoma Attorney General, beginning in 2004, to evaluate, provide analysis regarding and to advise on matters pertaining to poultry waste generation, poultry waste disposal practices and the fate and transport of land applied poultry waste.

Summary of Opinions

1. Defendants' actions and practices have polluted surface water, ground water, soil and sediment within the Illinois River Watershed.

2. Defendants have a long and substantial history of poultry production within the Illinois River Watershed.

3. The contaminants of concern within the Illinois River Watershed are phosphorous and bacteria.

4. Poultry are the primary contributors to the phosphorus pollution of soils, surface waters, ground waters, and sediments within the Illinois River Watershed.

5. Poultry are highly significant contributors to bacterial pollution of surface and ground water within the Illinois River Watershed.

6. The population of poultry within the Illinois River Watershed has shown an overall increase since at least 1950.

7. The amount of waste generated by poultry with in the Illinois River Watershed has increased since at least 1950.

8. A substantial mass of poultry waste is produced within the Illinois River Watershed.

9. Poultry waste is disposed by land application without incorporation (simple broadcast spreading).

10. Waste generated by poultry within the Illinois River Watershed has been applied near to where it is generated.

11. Poultry waste has been widely disposed on pasture and grasslands within the Illinois River Watershed.

12. Poultry waste generated by poultry within the Illinois River Watershed is disposed year-round, but is dominantly disposed from late winter through spring.

13. All Defendants have disposed of poultry waste within the Illinois River Watershed.

14. The mass of poultry waste generated within the Illinois River Watershed but disposed of outside the watershed is a minority of the waste generated within the Illinois River Watershed.

15. Defendants' feed formulas show that Defendants add chemical compounds, including compounds containing phosphorous, and metals (sodium, potassium, calcium, copper, zinc, arsenic and selenium).

16. Because of the addition of compounds containing phosphorous and metals (including sodium, potassium, calcium, copper, zinc and arsenic), poultry waste contains high levels of nutrients, including phosphorous, and metals (including sodium, potassium, calcium, copper, zinc and arsenic).

17. The chemistry of cattle diets differs from that of poultry diets.

18. The chemical composition of poultry waste is distinctly different from the chemical composition of cattle waste and waste water treatment plant effluent.

19. The geology of the Illinois River Watershed produces a circumstance in which both the surface and ground water within the Illinois River Watershed are highly susceptible to pollution from the constituents of land applied poultry waste.

20. Shallow ground water within the Illinois River Watershed is highly susceptible to contamination from surface-applied pollutants.

21. Constituents of land disposed poultry waste run off fields and surface water and infiltrate through geologic media and contaminate ground

water and are poorly attenuated.

22. Soils to which poultry waste has been applied within the Illinois River Watershed are contaminated by poultry waste constituents.

23. Runoff water captured in edge of field (EOF) samples within the Illinois River Watershed is contaminated by poultry waste.

24. Ground water within the Illinois River Watershed is contaminated by poultry waste.

25. Stream Sediments within the Illinois River Watershed are contaminated by poultry waste

26. Reservoir sediments are important archives of environmental and geomorphic processes occurring within their drainage basins.

27. Sediment has accumulated in Lake Tenkiller since dam closure.

28. Poultry waste constituents have accumulated and are accumulating within the sediments of Lake Tenkiller, and sediment concentrations of phosphorous and other poultry waste constituents within Lake Tenkiller sediments have increased over time.

29. The change in sediment concentrations of and other poultry waste constituents within Lake Tenkiller sediments are directly related to changes in poultry production within the Illinois River Watershed.

applied in large quantities leading to potential to impact water quality. The BMPs Inc. proposal for transport of a small portion of the poultry waste out of the Illinois River Watershed was built on this premise. The USDA published that a significant part of the water quality problems in the Illinois River Watershed were the result of the large amount of poultry waste generated and disposed within the watershed.[80] Non-point source modeling work conducted in the Illinois River Watershed found that a maximum poultry waste transport distance of 8000m (approximately five (5) miles) from poultry houses in the Illinois River Watershed provided the best observed fit between estimated soil test phosphorus and observed soil test phosphorus.[81] Data obtained from the Arkansas Soil and Water Conservation Commission show that substantial amounts of poultry waste were applied in the Illinois River Watershed during the period 2004-2007 (see Table 7). [82] Lastly, the Defendant's own experts assumed all poultry waste produced in the Illinois River Watershed was land applied within the Illinois River Watershed.[83]

Table 7.
Arkansas Soil and Water Conservation Commission Estimate of Poultry Waste Land Applied in the Illinois River Watershed
(all data in tons)

	Year			
County	2004	2005	2006	2007
Benton	11,440	7,925	5,935.75	36,180
Washington	24,457	19,269	20,009	30,010

11. Poultry waste has been widely disposed on pasture and grasslands within the

Arkansas.

80 USDA SCS and FS. 1992. Illinois River Cooperative River Basin Resource Base Report.

81 Storm, D.E., G.J. Sabbagh, M.S. Gregory, M.D. Smolen, D. Toetz, D.R. Gade, C.T. Haan, T. Kornecki. 1996. Basin-Wide Pollution Inventory for the Illinois River Comprehensive Basin Management Program. Oklahoma State University. Submitted to the Oklahoma Conservation Commission for the US EPA , Final Report.

82 Arkansas Soil and Water Conservation Commission District Reports for Washington and Benton County, Arkansas 2004-2007.

83 Rausser, G. And M. Dicks. 2008. Declaration of Dr. Gordon Rausser and Dr. Michael Dicks in Opposition to Plaintiff's Motion for Preliminary Injunction.

Illinois River Watershed. ODAFF records[84], nutrient management plans in Defendants' discovery documents[85] , and investigator notes[86] demonstrate that poultry waste has been applied on pasture and grasslands throughout both the Oklahoma and Arkansas portions of the Illinois River Watershed. Shown in Fig. 6 are Public Land Survey sections in which poultry waste is known to have been disposed within the Illinois River Watershed based on ODAFF records, investigator reports and discovery documents. This map demonstrates that poultry waste disposal is widespread throughout grassland and pasture areas within the Illinois River Watershed.

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84 PI-Fisher00027498-00031831.

85 TSN19381SOK-TSN19435SOK; TSN20629SOK-TSN20640SOK; TSN20598SOK-TSN20628SOK; TSN20569SOK-TSN20595SOK; TSN20561SOK-TSN20568SOK; TSN20538SOK- TSN20556SOK; TSN19835SOK-TSN19846SOK; TSN19241SOK-TSN19257SOK; TSN18746SOK-TSN18757SOK; TSN20517SOK-TSN20529SOK; TSN20504SOK-TSN20516SOK; TSN20470SOK-TSN20503SOK; TSN20480SOK-TSN20503SOK; TSN20455SOK-TSN20469SOK; TSN19685SOK-TSN19708SOK; TSN20417SOK-TSN20425SOK; TSN19098SOK-TSN19127SOK; TSN20403SOK-TSN20416SOK; TSN19847SOK-TSN19874SOK; TSN19875SOK-TSN19885SOK; TSN19278SOK-TSN19293SOK; TSN20381SOK-TSN20402SOK; TSN20372SOK-TSN20380SOK; TSN19294SOK-TSN19308SOK; TSN19294SOK-TSN19294SOK; TSN20300SOK-TSN20335SOK; TSN20426SOK-TSN20454SOK; TSN20431SOK-TSN20454SOK; TSN19804SOK-TSN19817SOK; TSN20171SOK-TSN20264SOK; TSN20252SOK-TSN20264SOK; TSN20118SOK-TSN20170SOK; TSN20088SOK-TSN20117SOK; TSN20051SOK-TSN20087SOK; TSN19993SOK-TSN20050SOK; TSN19900SOK-TSN19908SOK; TSN19197SOK-TSN19222SOK; TSN20186SOK-TSN20216SOK; TSN19886SOK-TSN19895SOK; TSN20336SOK-TSN20346SOK; TSN18819SOK-TSN18835SOK; TSN18836SOK-TSN18903SOK; TSN19672SOK-TSN19682SOK; TSN18929SOK-TSN18918SOK; TSN18930SOK-TSN18943SOK; TSN18791SOK-TSN18801SOK; TSN07386SOK-TSN07401SOK; TSN19128SOK-TSN19151SOK; TSN19709SOK-TSN19776SOK; TSN19726SOK-TSN19776SOK; TSN18716SOK-TSN18735SOK; TSN19777SOK-TSN19783SOK; TSN19152SOK-TSN19189SOK; TSN18687SOK-TSN18715SOK; TSN18554SOK-TSN18589SOK; TSN18944SOK-TSN18956SOK; TSN18661SOK-TSN18686SOK; TSN18667SOK-TSN18686SOK; TSN18977SOK-TSN19005SOK; TSN19479SOK-TSN19495SOK; TSN19591SOK-TSN19623SOK; TSN59962SOK-TSN59985SOK; TSN61804SOK-TSN61822SOK; TSN60176SOK-TSN60192SOK; TSN62084SOK-TSN62090SOK; TSN60502SOK-0TSN61603SOK; TSN60679SOK-TSN60711SOK; TSN115069SOK-TSN115091SOK; TSN115092SOK-TSN115112SOK; TSN115113SOK-TSN1151132OK; TSN61878SOK-TSN61899SOK; TSN61528SOK-TSN61537SOK; TSN60756SOK-TSN60770SOK; TSN47940SOK-TSN47956SOK; TSN60030SOK-TSN60046SOK; TSN59901SOK-TSN59916SOK; TSN60503SOK-TSN60507SOK; TSN72021SOK-TSN72032SOK; PFIRWP-01058-PFIRWP-01097; PFIRWP-000185-PFIRWP-000195; PFIRWP-000703-PFIRWP-001427; PFIRWP-000317-PFIRWP-000330; PFIRWP-000383-PFIRWP-000383; PFIRWP-000333-PFIRWP-000346; PFIRWP-060344-PFIRWP-060377; PFIRWP-000690-PFIRWP-000702; PFIRWP-000459-PFIRWP-000461; PFIRWP-000489-PFIRWP-000515; PFIRWP-000565-PFIRWP-000589; PFIRWP-000108-PFIRWP-000113; PFIRWP-024980-PFIRWP-024983; GE4030-GE4046; GE7055-GE7076; GE34065-GE34081; GE34209-GE34245; GE2357-GE2351; GE34003-GE34013; GE34147-GE34163; Cal-Maine East Farm; Cal-Maine West-East appl Sites; Cal-Maine West-East Farms IRW; Dick Latta SunBest Farm; Dick Latta SunBest Farm appl sites 2; CM-000003160-CM-000003204; CM-000002945-CM000003132.

abundant in poultry waste than in cattle waste and 7.4 times more abundant in poultry waste than in wastewater treatment plant effluent.

Given these differences in chemical ratios, these wastes are distinctly different from one another, and these differences can be used to identify the presence of these wastes in environmental samples.

Table 12.
Ratios of Total Zn/Total P, Total Cu/Total P, Total As/Total P and Total Zn/Total Cu for Poultry Waste, Cattle Waste and Wastewater Treatment Plant Effluent (unfiltered)

		Total Zn / Total P	Total Cu/'Total P	Total As/Total P	Total Zn/Total Cu
Poultry Waste	Maximum	0.130	4.662	1.896	4.757
	Q3	0.107	4.277	1.460	1.367
	Mean	0.085	3.370	0.799	1.317
	Median	0.086	3.694	0.861	1.115
	Q1	0.064	2.986	0.121	1.034
	Minimum	0.022	0.210	0.025	0.893
Cattle Waste	Maximum	0.007	0.039	As not detected	8.901
	Q3	0.004	0.034	As not detected	6.852
	Mean	0.004	0.029	As not detected	6.102
	Median	0.004	0.028	As not detected	5.955
	Q1	0.003	0.024	As not detected	5.431
	Minimum	0.002	0.022	As not detected	4.237
Wastewater Treatment Plant Effluent	Maximum	0.000007	0.000045	0.000063	14.190
	Q3	0.000006	0.000028	0.000062	12.427
	Mean	0.000004	0.000022	0.000060	9.762
	Median	0.000004	0.000017	0.000060	9.563
	Q1	0.000003	0.000011	0.000058	6.897
	Minimum	0.000001	0.000011	0.000054	5.731

19. The geology of the Illinois River Watershed produces a circumstance in which both the surface and ground water within the Illinois River Watershed are highly susceptible to pollution from the constituents of land applied poultry waste. The Illinois River Watershed contains approximately 1,672 mi^2 (1,069,530 acres), and lies within the southwestern portion (Springfield Plateau) of the Ozark Uplift physiographic province within portions of Washington and Benton Counties in Arkansas and Delaware, Adair, Cherokee and Sequoyah Counties in Oklahoma. Approximately 53% of the Illinois River Watershed is in Oklahoma and the remaining 47% is in Arkansas.[103] The Springfield plateau is generally deeply dissected with rolling upland areas separated by V-shaped stream valleys that range from 20 to 30 feet in depth.

As shown in Fig 9, the Illinois River arises in the Boston Mountains of northwestern Arkansas in Washington County. From its headwaters, it flows in a northerly and westerly direction to its crossing of the Oklahoma/Arkansas border south of Siloam Springs in Benton Country, Arkansas. From there, the Illinois continues westerly to its confluence with Flint Creek in Delaware County, Oklahoma where it changes course to a southerly direction. The Illinois is impounded by Tenkiller dam just north of its confluence with the Arkansas River at Gore, Oklahoma. From its headwaters to its confluence with the Arkansas, the Illinois flows approximately 162 miles.

Two of the primary tributaries to the Illinois River also arise in the Ozark region of Arkansas. Flint Creek originates in Benton Country and flows generally wesferly toward its confluence with the Illinois just south of Kansas, Oklahoma. Baron Fork Creek arises in Washington County, Arkansas and flows southwesterly to its confluence with the Illinois south of Tahlequah, Oklahoma. The third major tributary to the Illinois River, Caney Creek, originates at Stillwell, OK and flows generally southwesterly to its confluence with the Illinois in the northern portion of Lake Tenkiller.

Surface water movement within the Illinois River Watershed is controlled by its underlying geology. The major streams in the Illinois River Watershed (Illinois River, Flint Creek, Baron Fork and Caney Creek) have developed within geological faults and fractures.[104] As shown

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103 Lyhane. T. E., 1987. Hydrologic Investigation of the Illinois River. Technical Report 87-3. Oklahoma Water Resources Board, Stream Water Division.

104 Adamski, J. C., J. C. Peterson, D. A. Freiwald and J. V. Davis. 1994. Environmental and hydrologic setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma, USGS WRI 94-4022 ((PI-Fisher00002644 - PI-Fisher00002719) ; Salisbury, D. O. and Davis, R. K. 1997. A hydrogeological and hydrochemical connection between the Decatur City Spring and Crystal Lake,

in the digital elevation map given in Fig 10, these streams flow westerly and southwesterly, and become, in general, progressively more deeply incised as they pass from the Arkansas portion of the Illinois River Watershed to the Oklahoma portion of the Illinois River Watershed. As shown on the land use/land cover map in Fig 11, the Arkansas portion of Illinois River Watershed is dominated by broad open grassed areas of low topographic relief that are dissected by numerous tributary drainages. In contrast, in the Oklahoma portion of the Illinois River Watershed, topographic relief is greater, and the major streams there form broader more steeply-sided forested valleys that separate more isolated grassed areas. Urban areas within the Illinois River Watershed are located largely along the watershed's boundary, dominantly along the far northeastern boundary of the watershed, and adjacent to the primary east-west transportation corridor. Simply stated, the Arkansas portion of the Illinois River Watershed is more open, contains a greater proportion of pasture land and those pasturelands are more contiguous in Arkansas than in Oklahoma. This condition facilitates the disposal of poultry wastes through land application. In contrast, the Oklahoma portion of the Illinois River Watershed is generally hillier, going westward and southwestward, and thus becomes less topographically suitable for the disposal of poultry wastes through land application traveling from east to west.

Structural features found in the region suggest episodes of uplift and extensional stress. Compressional forces are attributed to the Ouachita orogeny, a plate collision that climaxed in the Mississippian.[105] Extensional forces are represented by large-scale normal faults, dipping to the south that commonly extend to basement[106], and smaller scale faulting on

Benton County, Arkansas. J. Arkansas Academy of Science, 51: 159 – 168 (PI-Fisher00000092- PI-Fisher00000101); Bedrock Geologic Map of Arkansas, Northwest Quadrant, 1800x1600, available at http://geology.about.com/library/bl/maps/n_statemap_ARnw.htm; also see PI-FISHER00026686.

105 Flawn, P.T., Goldstein, A. Jr, King, P.D., and Weaver, C.E., 1961, The Ouachita System, The University of Texas, Austin, TX.

106 Orndorff, R.C., Weary, D.J., Sebela, S., 2001, Geologic Framework of the Ozarks of South-Central Missouri- Contributions to a Conceptual Model of Karst, In Eve L. Kuniansky, editor, 2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011, p. 18-24.

the order of 30 m displacements.[107] Joints are common and appear to be controlled by uplift that resulted in extensional fractures. The faults and fractures that control drainage within the Illinois River Watershed are primarily associated with the Ozark uplift. The Ozark uplift postdates the deposition of the youngest bedrock (Mississippian) within the Illinois River Watershed.[108] As a result, this uplift disturbed all strata within the Illinois River Watershed. Consequently, significant fracturing and faulting observed at the surface within the Illinois River Watershed penetrates deeply into all of the geologic formations within the Illinois River Watershed. This deep fracturing is significant, because its presence means that the constituents from land application of poultry waste can not only easily move into shallow aquifers along dissolution-expanded (karsted) infiltration routes, it can also penetrate to greater depths along the deep seated fractures and faults, and thus threaten deeper aquifers. A map showing major faults fractures and significant linemaments is given in Fig 12.

The terrain of the bulk of the Illinois River Watershed is mantled karst.[109] In mantled karst terrains the dissolution of carbonate units beneath a covering of soil and regolith creates expanded infiltration pathways including, sinkholes, solution expanded fractures, faults and caves. The fracturing and faulting within the Illinois River Watershed, combined with karstification (which enlarges subsurface faults and fractures) produces areas of high

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107 Stanton, G.P., and Brahana, J.V., 1996, Structural control on hydrogeology of a mantled karst aquifer in northwestern Arkansas: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. 334.

108 Hudson, M. R. 2000. Coordinated strike-slip and normal faulting in the southern Ozark dome of northern Arkansas: Deformation in a late Paleozoic foreland. Geology, 28:511-514 (PI-Fisher00001752- PI-Fisher00001755); Imes, J. L. and L. F. Emmett. 1994. Geohydrology of the Ozark Plateaus Aquifer System in Parts of Missiouri, Arkansas, Oklahoma and Kansas. USGS Professional Paper 1414-D (PI-Fisher00002912. - PI-Fisher00003051).

109 Stanton, G.P., and Brahana, J.V., 1996, Structural control on hydrogeology of a mantled karst aquifer in northwestern Arkansas: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. 334; Adamski, J. C., J. C. Peterson, D. A. Freiwald and J. V. Davis. 1994. Environmental and hydrologic setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma, USGS WRI 94-4022 ((PI-Fisher00002644 - PI-Fisher00002719) ; Salisbury, D. O. and Davis, R. K. 1997. A hydrogeological and hydrochemical connection between the Decatur City Spring and Crystal Lake, Benton County, Arkansas. J. Arkansas Academy of Science, 51: 159 – 168 (PI-Fisher00000092- PI-Fisher00000101).

permeability, and results in a circumstance in which shallow ground water aquifers are particularly susceptible to impact by surface contamination, including contamination by bacteria, that can readily travel from the soil surface to surface water and ground water during rainfall events. A diagram illustrating the relationship between fractures and solution activity in carbonate rocks is provided in Fig 13. Within such a karst terrain, there is little attenuation (reduction) of contaminants as they move from the land surface into and through the karst aquifer. Thus, land application of poultry waste to the karst terrain of the Illinois River Watershed means that constituents of this waste (including bacteria) travel readily through the soils and underlying geologic media to discharge at and into ground water springs and surface streams throughout the Illinois River Watershed. Further, because of the ready flow of water through a karst terrain of the type present in the Illinois River Watershed, there is strong interaction between surface water flow and ground water flow so that surface waters readily become ground water and ground water readily becomes surface water. The phenomenon is readily shown by the numerous springs and gaining and losing streams found within the Illinois River Watershed.

Soils within the Illinois River Watershed are formed mostly from the weathering of carbonate rocks, and are of low natural fertility.[110] The soils are typically loams and are often rocky due to the presence of chert fragments. Loam soils are mixtures of sand, silt, clay and organic matter. Depending on the relative proportion of sand, silt and clay, these

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110 Osborn, N. L. 2001. Minor Basin Hydrogeologic Investigation Report of the Boone Groundwater Basin, Northeastern Oklahoma. Oklahoma Water Resources Board Technical Report GW2001-2. (PI-Fisher00003605 - PI-Fisher00003630); United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1977. Soil Survey of Benton County, Arkansas; United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1969. Soil Survey of Washington County, Arkansas; U.S. Dept. of Agriculture, Soil Conservation Service. 1965. Soil survey, Adair County, Oklahoma; U.S. Dept. of Agriculture, Soil Conservation Service. 1970. Soil survey, Cherokee and Delaware Counties, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Adair County, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Delaware County, Oklahoma.

soils will be susceptible to infiltration or surface runoff.[111] As shown in Fig 14, soils more susceptible to run off dominate in the eastern and western portions of the Illinois River Watershed, while soils that are more susceptible to infiltration dominate in the central portion of the Illinois River Watershed.[112] Thus, contaminants deposited on the surface within the Illinois River Watershed are prone to runoff from soils in about half of the watershed and are prone to infiltration through soils in the remaining half of the watershed.

The features discussed above are schematically shown in Fig 15 which provides a site conceptual model for the Illinois River Watershed. The fractured and karsted bedrock is shown in brown in the cross section.

20. Shallow ground water within the Illinois River Watershed is highly susceptible to contamination from surface-applied pollutants. The shallow bedrock aquifer within the

111 Al-Qinna, M. I. 2003. Measuring and modeling soil water and solute transport with emphasis on physical mechanisms in karst topography. M.S. Thesis, University of Arkansas. . (PI-Fisher00003977- PI-Fisher00004270); Davis, R. K., J. V. Brahana, J. S. Johnson. 2000. Ground water in northwest Arkansas: Minimizing nutrient contamination from non-point sources in karst terrane. Arkansas Soil and Water Conservation Commission, Publication No. MSC-288 (PI-Fisher00003116 - PI-Fisher00003288); United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1977. Soil Survey of Benton County, Arkansas; United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1969. Soil Survey of Washington County, Arkansas; U.S. Dept. of Agriculture, Soil Conservation Service. 1965. Soil survey, Adair County, Oklahoma; U.S. Dept. of Agriculture, Soil Conservation Service. 1970. Soil survey, Cherokee and Delaware Counties, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Adair County, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Delaware County, Oklahoma.

112 The eastern portion of the Illinois River Watershed comprises upland soils belonging to hydrologic class "C", and to a lesser areal extent, soils within valley alluvium belonging to hydrologic class "B". The central portion of the Illinois River Watershed is dominated by soils belonging to hydrologic class "B", while the western portion of the Illinois River Watershed comprises soils belonging to hydrologic class "D". The least transmissive layer of soils belonging to hydrologic class "B" have a saturated hydraulic conductivity of between 1.42 – 5.67 in/hour (10-40 mm/s), and thus have much a greater infiltration potential (and, consequently, a much lower runoff potential) than soils in hydrologic class "C" in which the least transmissive layer has a saturated hydraulic conductivity of between 0.14 - 1.42 in/hour (1-10 mm/s) or soils in hydrologic class "D in which the least transmissive layer has a saturated hydraulic conductivity of < 0.14 in/hour (< 1 mm/s). See USDA NRCS 2007. National Engineering Handbook,

Springfield Plateau of the Ozark Uplift is the Boone. The Boone aquifer consists of the Mississippian Keokuk and Reeds Spring formations and the St. Joe Group, commonly called the Boone Chert or Boone Formation. The Boone Formation consists of dense, fine-grained limestone and massive gray chert. Where the chert is fractured, the formations are permeable[113.] The Boone aquifer is absent because of erosion in a few areas in Delaware, Cherokee, and Adair counties, Oklahoma. In these areas the Chattanooga Shale of Devonian age and the Burgen Sandstone, Sylvan Shale, and Cotter Dolomite of Ordovician age are exposed at the surface. The Burgen Sandstone and Cotter Dolomite are part of the underlying Roubidoux aquifer. [114]

The vulnerability of the Boone aquifer within the area of the Illinois River Watershed to pollution from surface-applied contaminants has been addressed in both Oklahoma[115] and Arkansas[116]. The aquifer vulnerability analysis conducted in Oklahoma and in Arkansas considered the same factors: (1) depth to water, (2) net recharge, (3) soil media, (4) topography, (5) vadose zone media; and (6) aquifer hydraulic conductivity.

The depth to water is the distance, in feet, from the ground surface to the water table. It determines the depth of material through which a contaminant must travel before reaching the aquifer. The shallower the water depth, the more vulnerable the aquifer is to pollution.

The primary source of recharge is precipitation, which infiltrates through the ground surface and percolates to the water table. Net recharge is the total quantity of water per unit area,

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Part 630 Hydrology, Chapter 7. Hydrologic Soil Groups.

113 Imes, J.L., and Emmett, L.F., 1994, Geohydrology of the Ozark Plateaus Aquifer System in Parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414-D, 127 p.; Marcher, M.V., and Bingham, R.H., 1971, Reconnaissance of the Water Resources of the Tulsa Quadrangle, Northeastern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 2, 4 sheets, scale 1:250,000.

114 Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1.

115 Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1.

in inches per year, which reaches the water table. Recharge is the principal vehicle for leaching and transporting contaminants to the water table. As recharge rate increases, opportunity for contaminants to reach the water table increases.

Soil media is the upper weathered zone of the earth, which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge that can infiltrate into the ground. In general, the less the clay shrinks and swells and the smaller the grain size of the soil, the less likely contaminants will reach the water table.

Topography refers to the slope of the land surface. Topography helps control the likelihood that a pollutant will run off or remain long enough to infiltrate through the ground surface. Where slopes are low, runoff is small, and the potential for pollution via infiltration is greater. Conversely, where slopes are steep, runoff capacity is high and the potential for pollution to reach ground water via infiltration is lower.

The vadose zone is the unsaturated zone above the water table. The texture of the vadose zone determines the time of travel of the contaminant through it. Coarse textured materials allow, in general, more rapid transport than finely textured materials.

Hydraulic conductivity refers to the rate at which water flows horizontally through an aquifer. Aquifer vulnerability increases with increasing hydraulic conductivity.

In Oklahoma, the Boone was among the four bedrock aquifers considered highly vulnerable to surface contamination because it contains karst features such as caves, sinkholes, and disappearing streams, which provide direct conduits for precipitation and runoff to transport contaminants to the water table.

116 The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Benton County. The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Washington County.

Recharge to the Boone hydrogeologic basin is almost entirely from direct infiltration of precipitation. The factors that make the outcrop of the Boone Formation favorable to ground water recharge also make it vulnerable to contamination. Because soil and subsoil in the Ozarks is thin, near-surface faults and fracture systems are common, and dissolution of the carbonate rocks is widespread, precipitation can quickly infiltrate the unsaturated zone.

Based on a review of Oklahoma Water Resources Board and Arkansas Geological Survey well records[117] there are 3,563 ground water wells in the Illinois River Watershed including 1,717 wells in the Oklahoma portion of the Illinois River Watershed. The vast majority of the wells in the Oklahoma portion of the Illinois River Watershed (1,679 of 1,717 wells, or 98%) are registered for "Domestic" use (for drinking and other household purposes), and about 50% of the wells in Oklahoma are shallow (i.e. less than 200' total depth). Based on my experience and observations these domestic wells do not typically employ treatment systems that would eliminate any bacterial hazard. Given the above analysis of the geology and terrain of the Illinois River Watershed, surface water contaminated with land applied poultry waste will readily travel to shallow, and often deep, ground water aquifers.

The analysis conducted for the Arkansas portion of the Illinois River Watershed[118] is more detailed spatially, and predicts that the highest areas of aquifer vulnerability are within fractures, stream courses and on slopes.

Considering the numerous factors in play that permit surface-applied contaminants to enter groundwater, the karst of northwestern Arkansas and northeastern Oklahoma is vulnerable to ground-water contamination because of the unique geology of the region in combination with the large volume of poultry waste spread on pasture land as fertilizer. The waste produced by more than I billion chickens and other poultry, and livestock operations

117 Groundwater well completion records for Oklahoma can be downloaded from www.owrb.ok.gov; Arkansas Reports on Water Well Construction (AWC-0001 - AWC-3852).

118 The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Benton County. The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Washington County.

constitutes a threat to ground-water quality because of rapid recharge of ground water through karst features and associated conduit flow of ground water through the bedrock.[119]

21. Constituents of land disposed poultry waste run off fields and surface water and infiltrate through geologic media and contaminate ground water and are poorly attenuated. Poultry waste is disposed on fields within the Illinois River Watershed by simple broadcast spreading. The poultry waste is not mechanically incorporated into soils. As a consequence, both soluble and particulate fractions of this material are readily available for transportation through the agency of rainfall. When rain interacts with poultry waste, some of the material goes into solution. This dissolved material can then travel with the water as it moves downward through the soil and vadose zone to pollute the ground water. Additionally, if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e. not all of the water can be taken up by the soil and it runs off the field). The dissolved material derived from the poultry waste will also move with the runoff and pollute surface water. Further, this runoff water can also carry particles of poultry waste that will pollute surface water, stream sediments and lake sediments. Because pores can be large in karst, particles can also be transported through the ground water in karst aquifers. Both runoff and ground water eventually end up in surface streams that flow to Lake Tenkiller. Thus pollution of the surface of the ground by the disposal of poultry waste as practiced within the Illinois River Watershed results in the pollution of surface water, ground water, stream sediments and lake sediments.

119 Davis, R. K., J. V. Brahana, J. S. Johnson. 2000. Ground water in northwest Arkansas: Minimizing nutrient contamination from non-point sources in karst terrane. Arkansas Soil and Water Conservation Commission, Publication No. MSC-288 (PI-Fisher00003116 - PI-Fisher00003288); Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1; Osborn, N. L. 2001. Minor Basin Hydrogeologic Investigation Report of the Boone Groundwater Basin, Northeastern Oklahoma. Oklahoma Water Resources Board Technical Report GW2001-2. (PI-Fisher00003605 - PI-Fisher00003630).

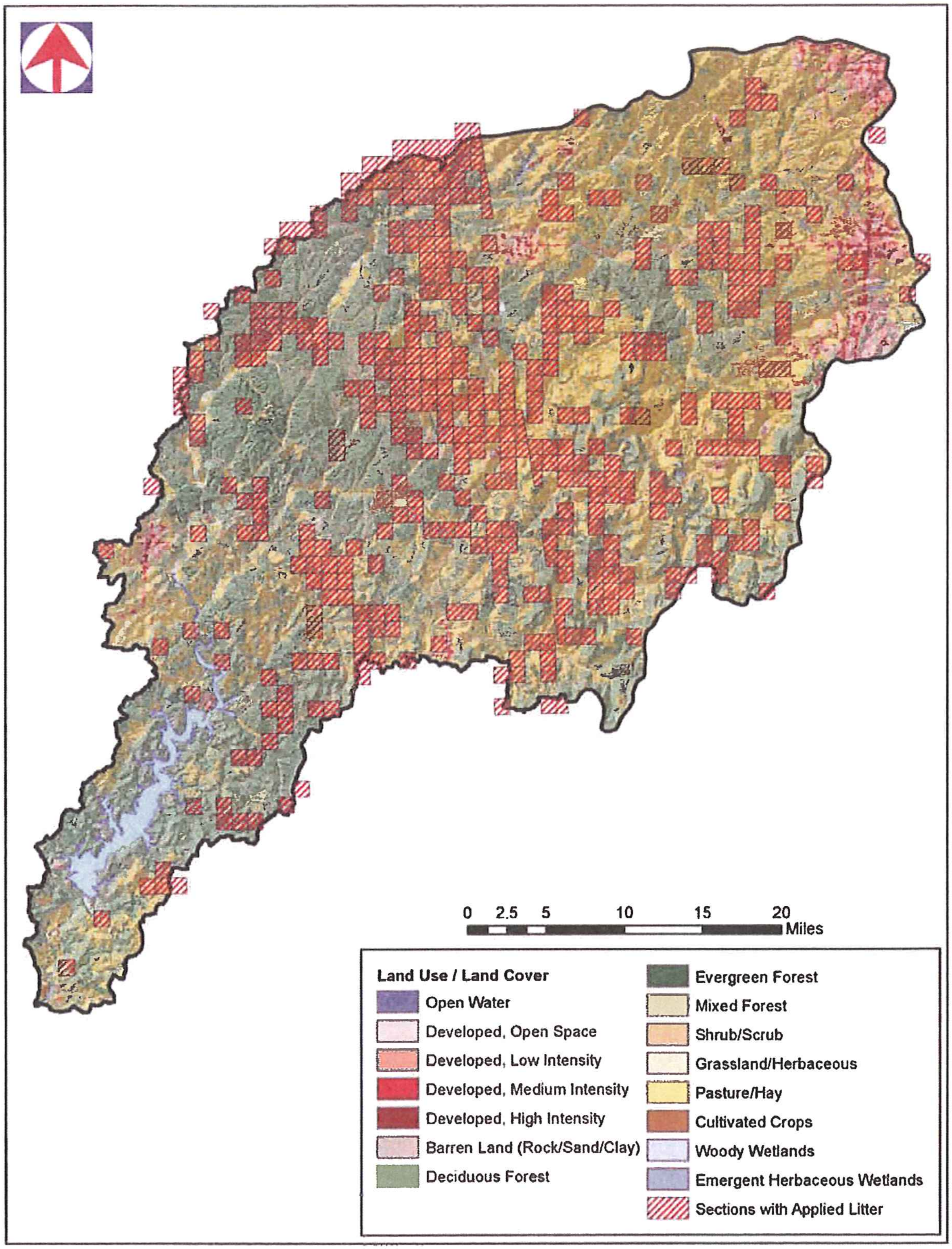

Figure 6. Public land survey sections in which poultry waste has been disposed within the Illinois River Watershed based on records maintained by the Oklahoma Department of Agriculture, Food and Forestry, investigator reports and Defendants' documents.

EXHIBIT
B